Scattering of Internal Gravity Waves at Finite Topography

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LONG-TERM GOAL

Description and modeling of the kinematic structure and the dynamical processes of oceanic internal gravity waves.

Understanding the role of internal gravity waves in the redistribution of momentum, potential vorticity, heat, and salt.

Development of a numerical model that predicts the internal wave field and the internal wave induced transports globally and regionally.

SCIENTIFIC OBJECTIVES

The current research project investigates the interaction of internal gravity waves with topography. Its specific objectives are:

- to assess the role of reflection and scattering at topography in the redistribution of energy within the internal wave band and in providing energy for boundary mixing.
- to determine the modifications of the deep ocean internal wave field when it propagates up the continental slope onto the shelf and to compare this remotely forced wave field with the locally generated field.

APPROACH

The scientific approach combines theoretical analysis with numerical modeling. The specific approach differs for scattering in two and three dimensions.

In two dimensions the method of characteristics can be employed. A general theoretical framework was developed by Baines (1971 a, b) and by Sandstrom (1976). The major challenges are the implementation of the radiation condition and the singularities at points where the topographic slope equals the wave slope.

In three dimensions, no general approach has been developed as yet. The governing equation is a hyperbolic equation which is analogous to the ordinary wave equation with the vertical coordinate replacing the time coordinate. This difference causes difficulties in solving this equation since the vertical space coordinate does not increase uniformly along the ray path in the bottom scattering problem.

WORK COMPLETED

In the two dimensional case we generalized Baines' (1971 a,b) theoretical results for an infinitely deep ocean to a finite-depth ocean. For applications a numerical model was developed for two types of topographic configurations: (a) a slope-shelf configuration with only one open sides and (b) a ridge configuration with two open sides. The model allows to study the scattering of an incoming internal wave at a smooth but otherwise arbitrary topography. Specifically, a suite of experiments is being conducted to study the scattering of an incoming deep-ocean internal wave field with a Garrett and Munk spectrum. The spectra of both the forward- and back-scattered internal wave field are calculated. From these spectra the redistribution of the wave energy in modenumber space is determined. If the energy flux is redistributed from low to high modenumbers a critical modenumber is determined, such that the Richardson number of all waves with modenumbers smaller than the critical modenumber equals the critical Richardson number 1/4. The energy flux to modenumbers larger than the critical modenumber excites waves that are likely to break and cause mixing. The energy flux past this critical modenumber is thus interpreted as being available for internal wave induced boundary mixing.

In three dimensions, we have developed an approach based on the Green's function of the governing wave equation. Following Hurley (1972) this Green's function is obtained by analytic continuation of the Green's function of the elliptic problem into the hyperbolic range. With this Green's function the scattering problem can be cast in to an integral equation for the topographic source of the scattered wave field and the scattered wave field itself. The approach correctly reproduces the scattering at a straight slope.

RESULTS

The numerical model runs for the two-dimensional case indicate that internal waves interact in a complex manner with topography. The picture that is slowly emerging from the model runs is that the redistribution of the energy flux does not only depend on the height and slope of the topography but also on its curvature, as has been anticipated by Gilbert and Garrett (1989). Results obtained from the use of piecewise linear topography should thus be used with caution.

IMPACT/APPLICATION

The research will help to clarify the role of open ocean internal for (a) boundary mixing, and (b) for processes on the continental slope and shelf.

TRANSITIONS

RELATED PROJECTS

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